

# Results on Diffraction at CDF



Angela Wyatt  
University College London  
for the CDF Collaboration



- **Introduction**
- **Improvements for run II**
- **Diffraction Dijets**
- **Double Pomeron Exchange Dijets**
- **Exclusive Diffraction**
- **Conclusions**

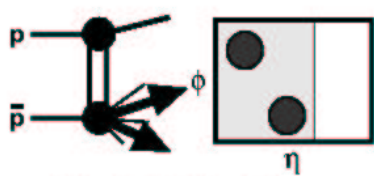
# Diffraction at CDF in Run I

## Diffraction

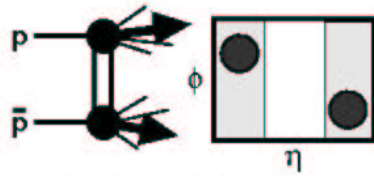
Experimentally: events containing a **rapidity gap** (or tagged p)  
- associated with pomeron exchange  
(carries vacuum quantum numbers)

## Run I Results

CDF made a wide range of diffractive measurements in Run I:



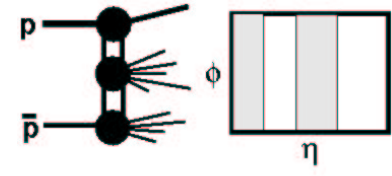
Single Diffraction



Double Diffraction



Double Pomeron Exchange



Multi-Gap Production

### Soft Diffraction

Single diffraction  
Double diffraction  
Multi-gap events

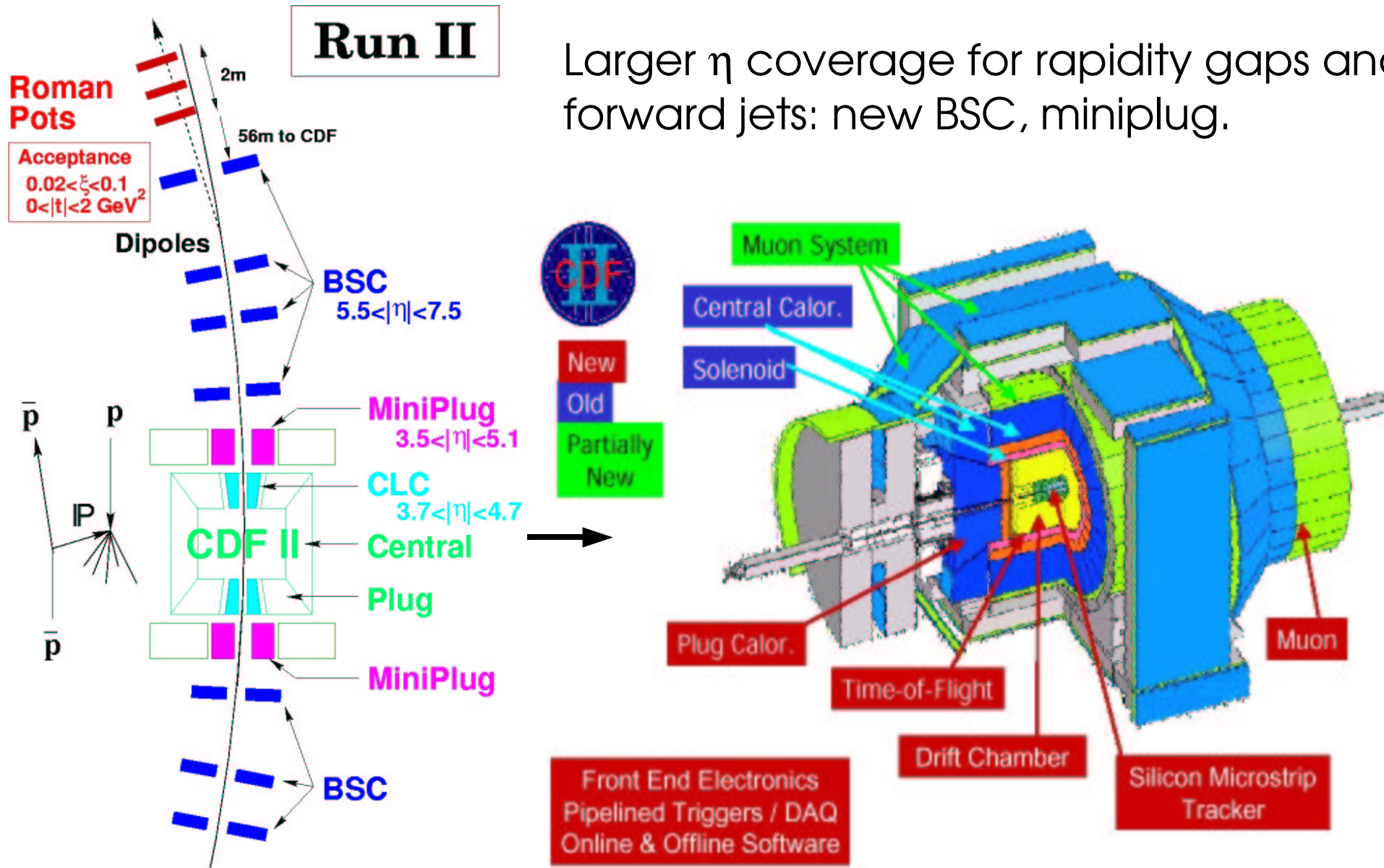
### Hard Diffraction

Single diffraction: dijets, W, b-quark, J/ψ  
Double diffraction: jet-gap-jet  
Double pomeron exchange: dijets

# Improvements for run II

## Run II

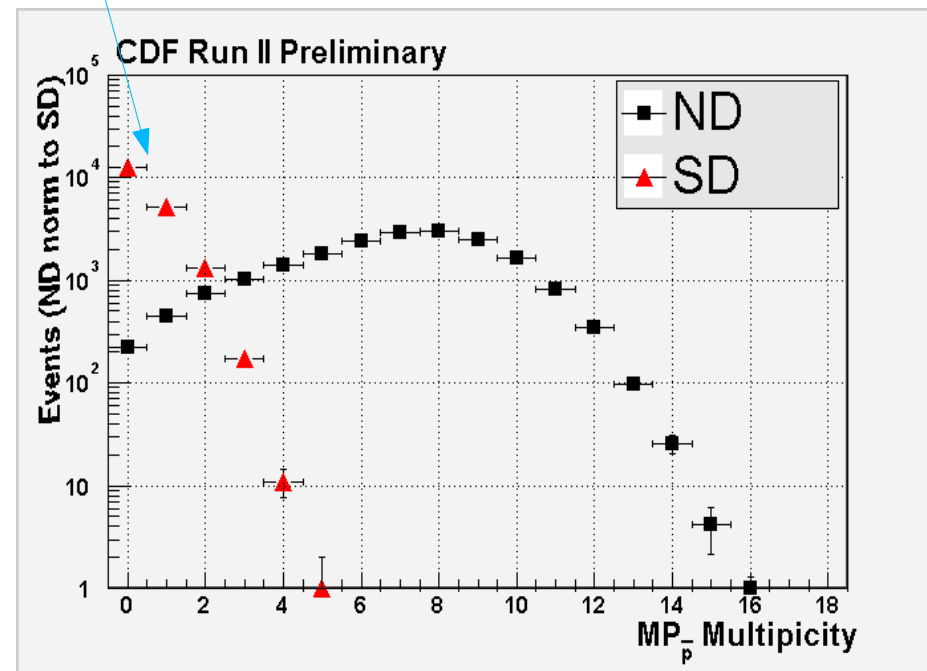
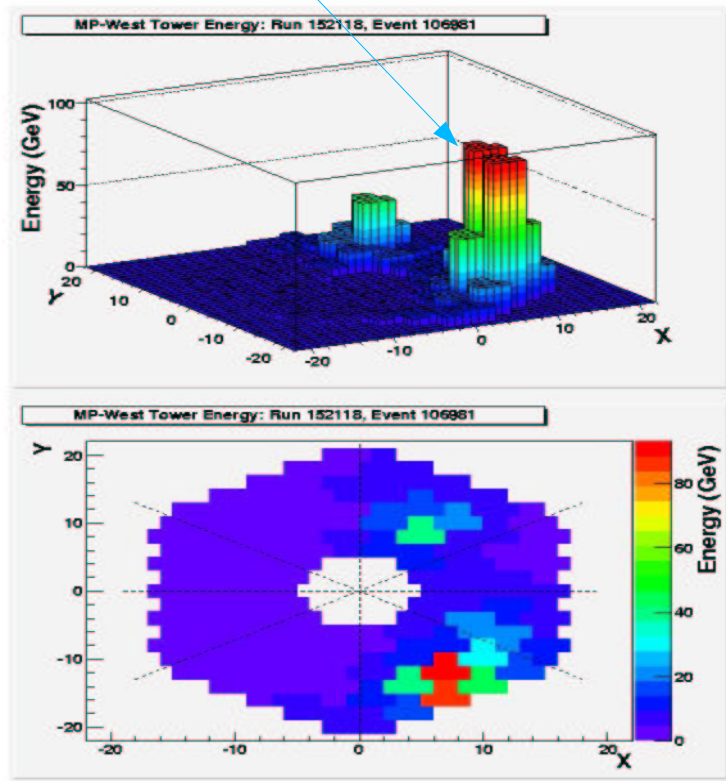
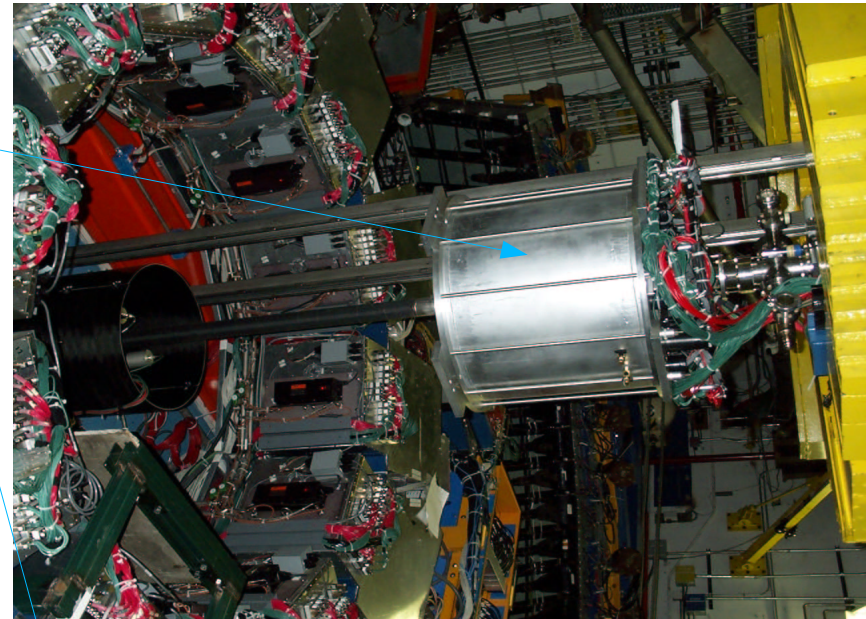
Larger  $\eta$  coverage for rapidity gaps and forward jets: new BSC, miniplug.



# The Miniplug Calorimeter

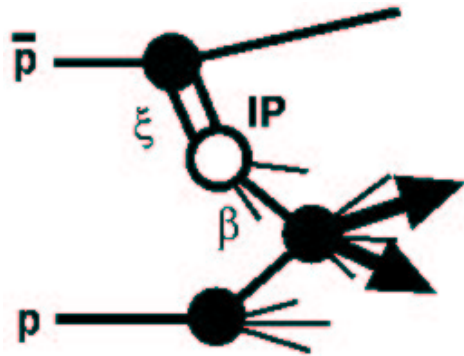
New Miniplug Detector enables:

- Select diffractive events from hit multiplicity
- Measure very forward jet energies





# Diffractive dijet production in run I

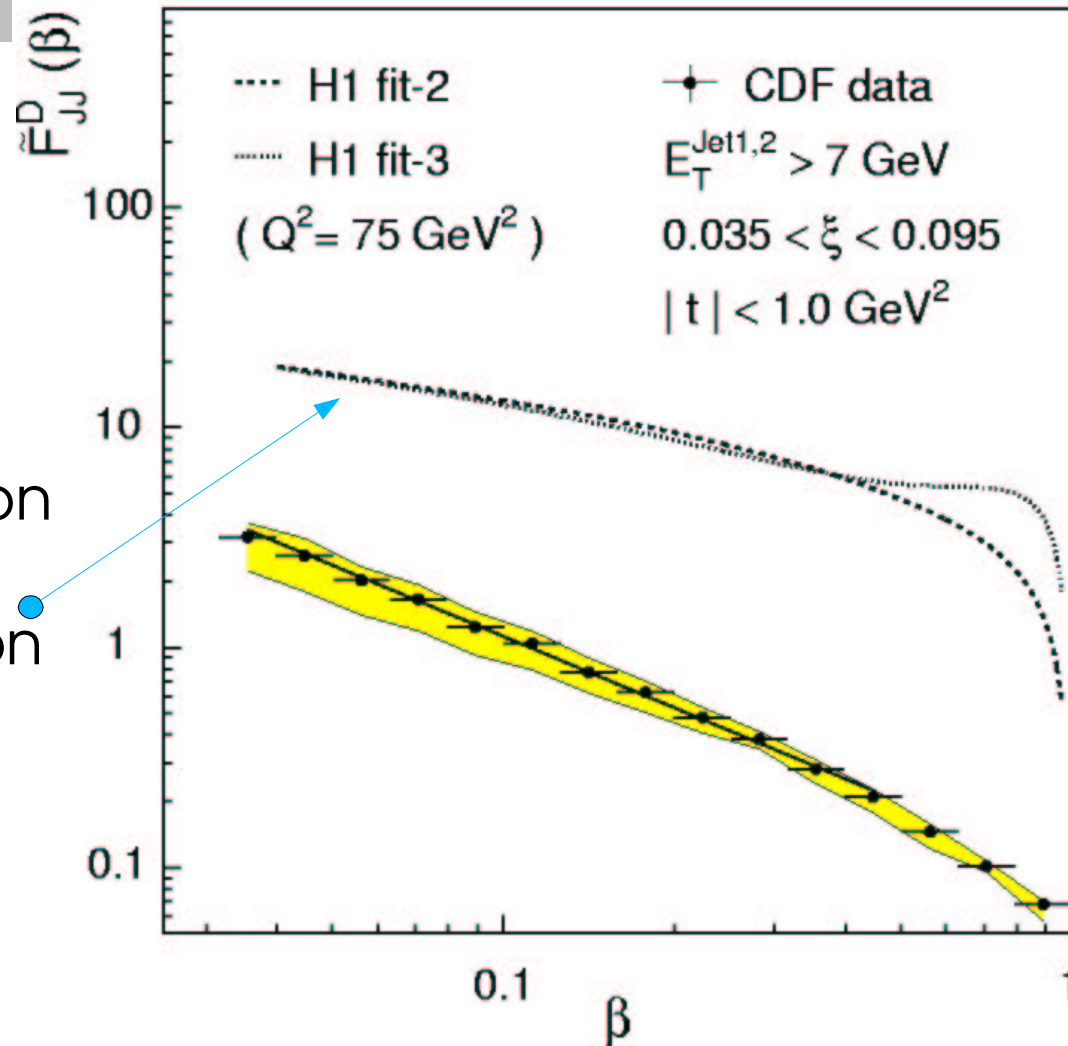


$\xi$  = Fraction of proton's mmtm carried by pomeron  
 $\beta$  = Fraction of pomeron's mmtm carried by parton  
 $x_{bj} = \xi\beta$

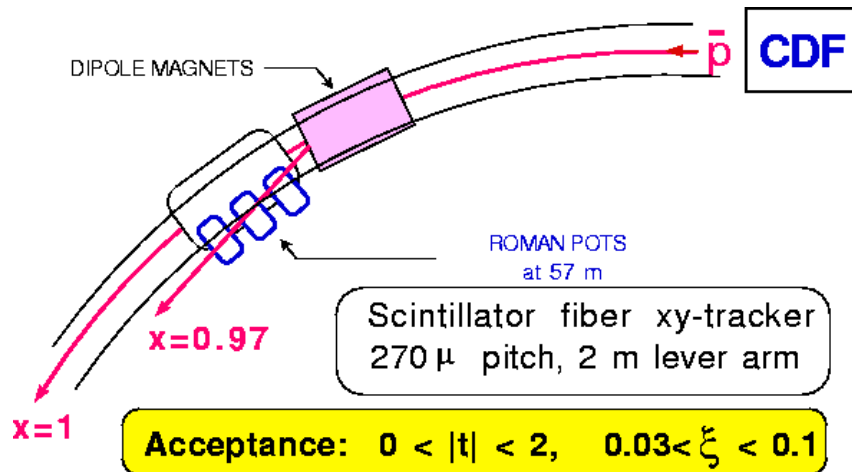
LO QCD:  $\frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F_{jj}^D(x)}{F_{jj}(x)}$

Diffractive structure function  
 also measured at [HERA](#)  
 $\Rightarrow$  expectation for Tevatron

$F_{jj}^D(\beta)$  suppressed relative to  
 expectation from HERA  
 parton densities



# Diffractive Dijets: event selection



Single diffractive (SD) dijets:

- Trigger on roman pot hit plus tower  $> 5$  GeV
- Select 2+ jets:  
corrected  $E_{\text{t}} > 5\text{GeV}$ ,  $|\eta_{1,2}| < 2.5$

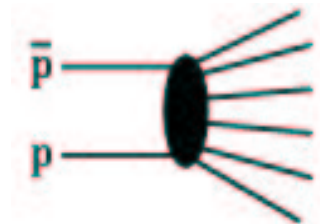
Non diffractive (ND) dijets:

As above, no roman pot hit.  
(control sample).

Variables:

$$x_{Bj} = \frac{\sum_i E_T^{jet} e^{-\eta_{jet}}}{\sqrt{s}}$$

$\xi$  see next slide.



Non-Diffractive  
(ND)



Single-Diffractive  
(SD)

# Measurement of $\xi$

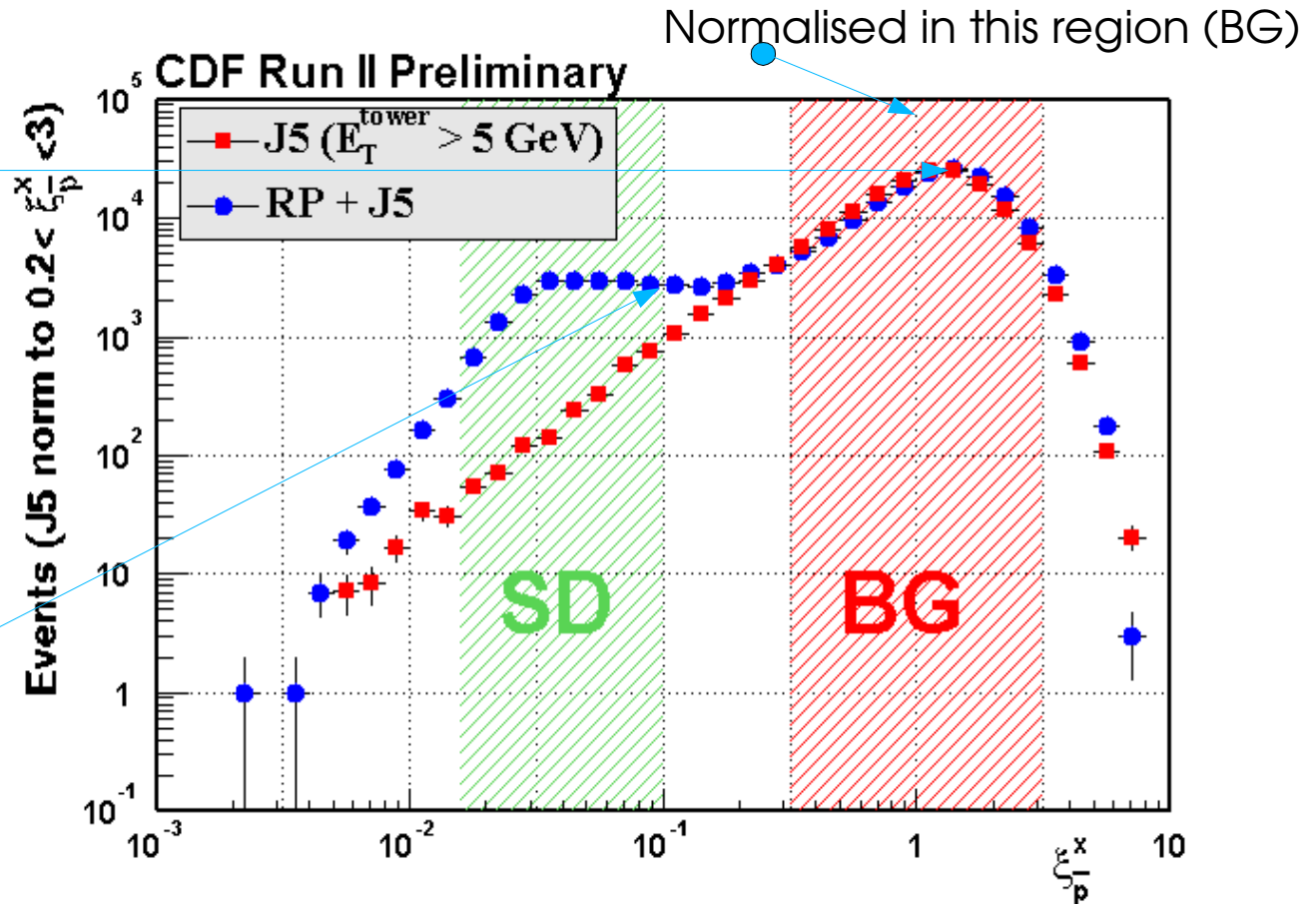
- Currently measured from **calorimetry**
- Sum over all calo. towers ( $|\eta| < 5.1$ )  
with  $E_{\text{T}} > 100 \text{ MeV}$
- MP E scale:  $\pm 25\% \rightarrow \Delta(\log \xi) \pm 0.1$
- **RP tracking** soon

$$\xi = \frac{M_X^2}{s} \approx \frac{\sum_i E_T^i e^{-\eta_i}}{\sqrt{s}}$$

Peak at  $\xi = 1$  from  
ND overlap events

$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \rightarrow \frac{d\sigma}{d(\log \xi)} = \text{Constant}$$

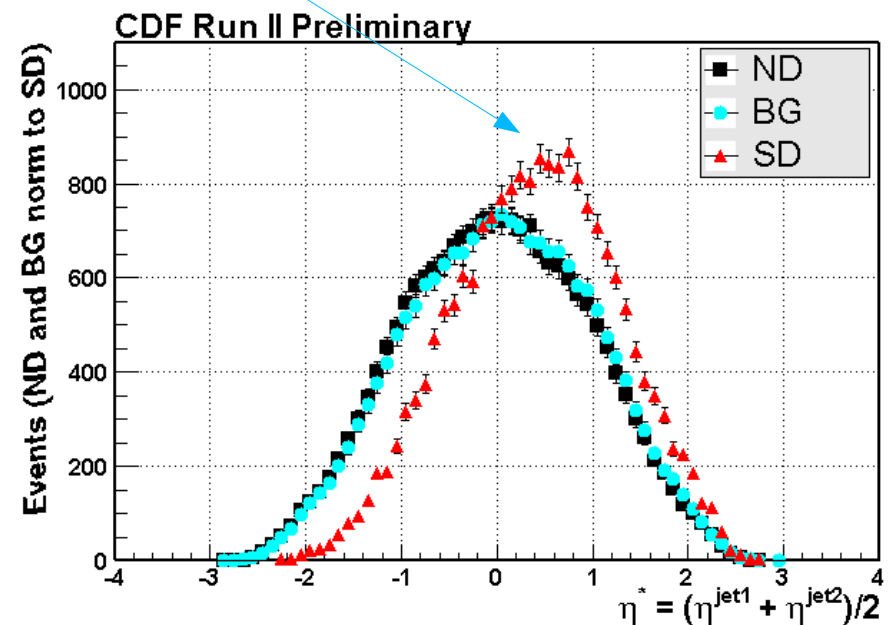
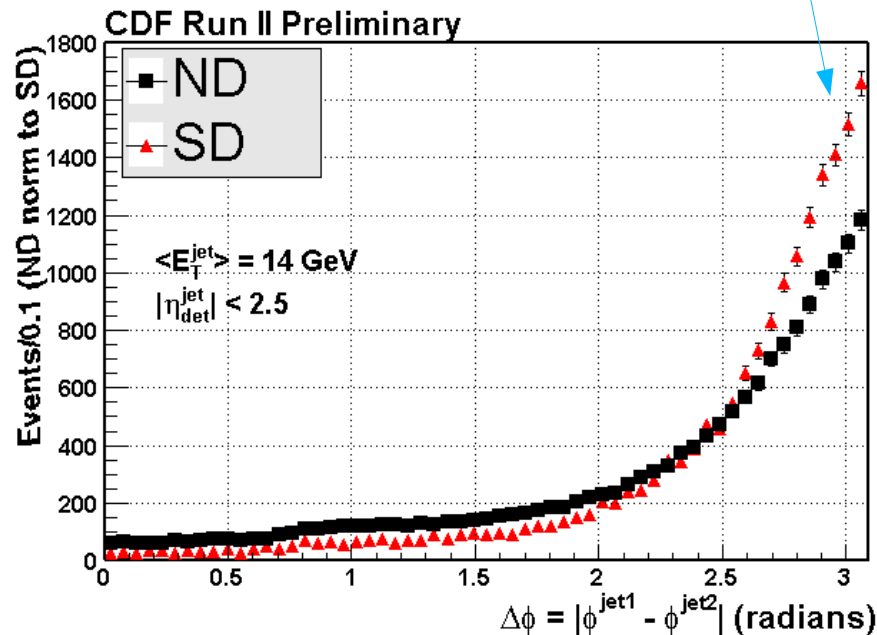
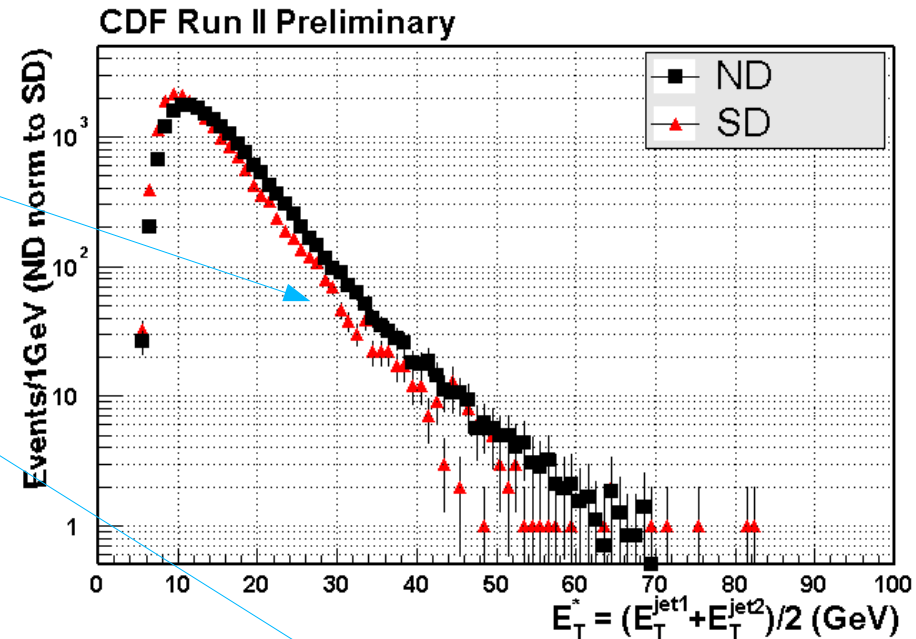
Approx. **flat** at  $\xi < 0.1$



# Diffraction Dijets: kinematic properties

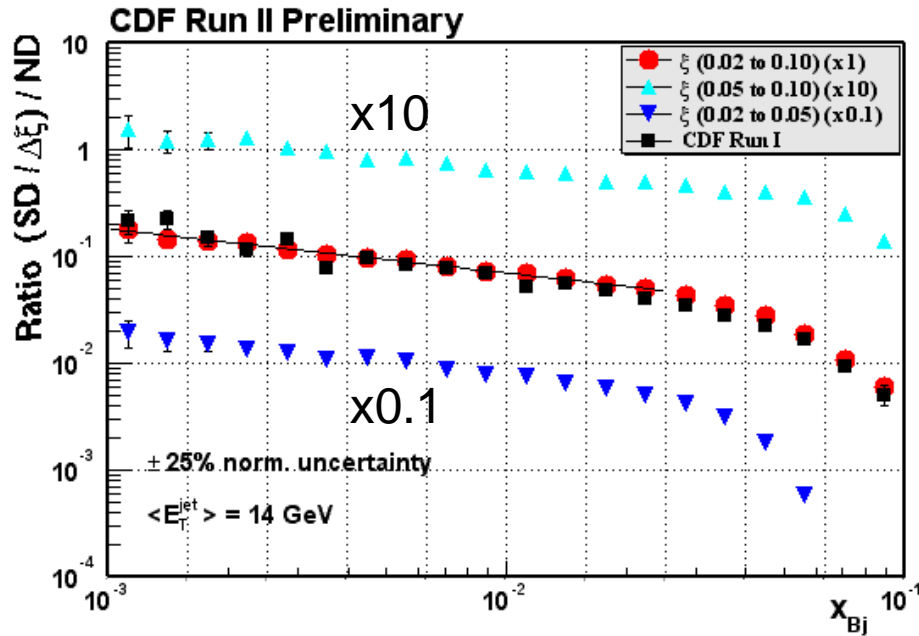
Jets in **SD** compared to **ND**:

- Slightly **steeper**  $E_T$  distribution
- **Boosted** in direction of outgoing proton ( $\xi \ll 1$ )
- More **back to back** in  $\phi$



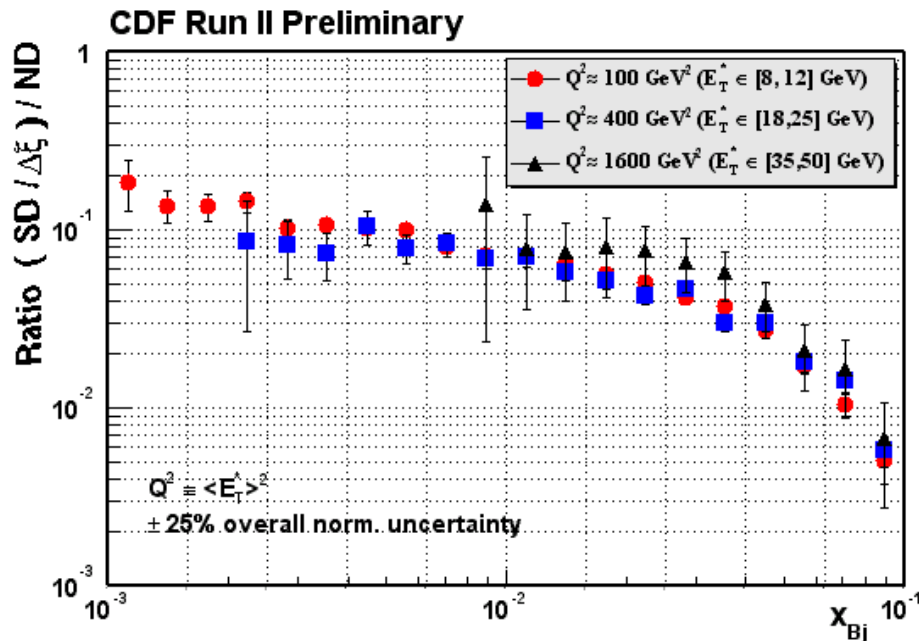


# Diffractive Dijets: structure function



SD/ND dijets - different  $\xi$  ranges

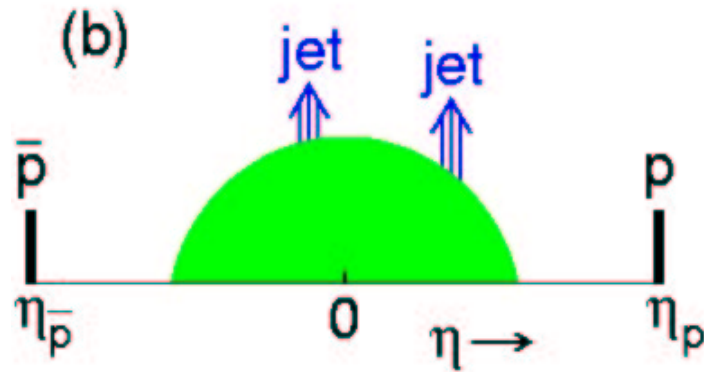
- Good agreement with run I in normalisation and  $x_{Bj}$  dependence
- No  $\xi$  dependence observed  
 $0.03 < \xi < 0.1$  (as in Run I)



SD/ND dijets - different  $Q^2$  ranges

- No significance  $Q^2$  dependence observed  
 $100 < Q^2 < 1600 \text{ GeV}^2$

# Double Pomeron Exchange in run I



$$p \bar{p} \rightarrow p + jjX + \bar{p}$$

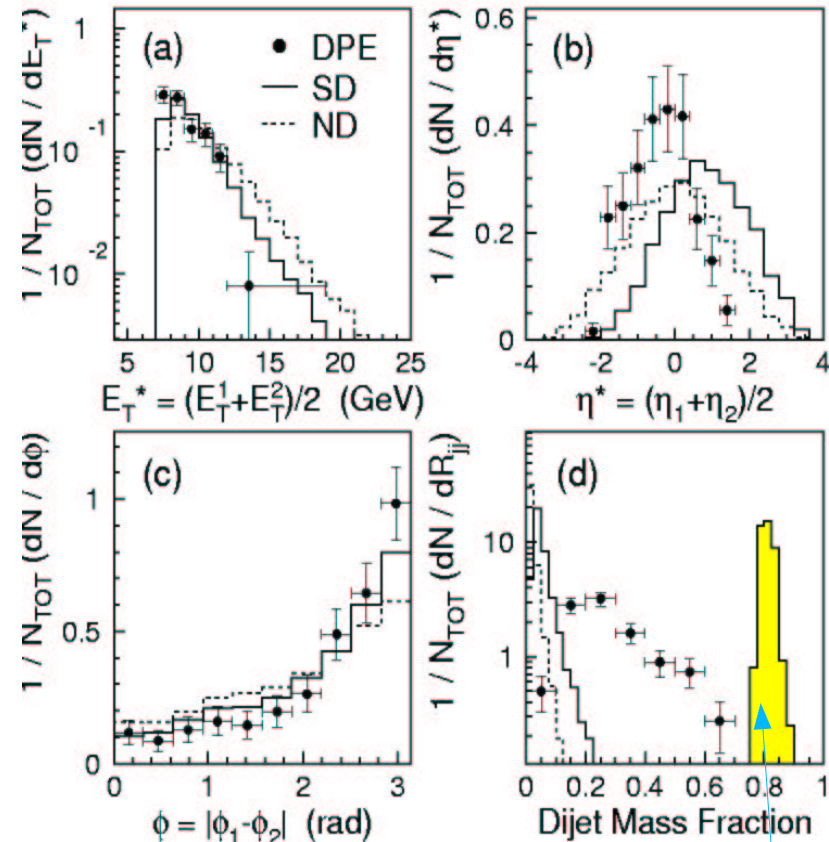
Tagged  $\bar{p}$ :  $0.035 < \xi < 0.095$   
 rapidity gap p side:  $0.01 < \xi < 0.03$   
 2 jets  $E_T > 7$  GeV

$\Rightarrow$  130 events

Mass Fraction:

$$R_{jj/X} = \frac{M_{jj}^{\text{cone}}}{M_X}$$

exclusive:  $0.7 < R_{jj/X} < 0.9$



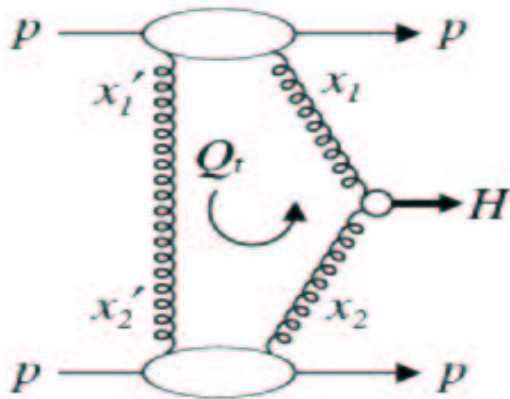
Inclusive  $\sigma = 43.6 \pm 4.4$  (stat)  $\pm 21.6$  (syst) nb

Exclusive  $\sigma < 3.7$ nb (95% C.L.)

# Interest in Exclusive DPE

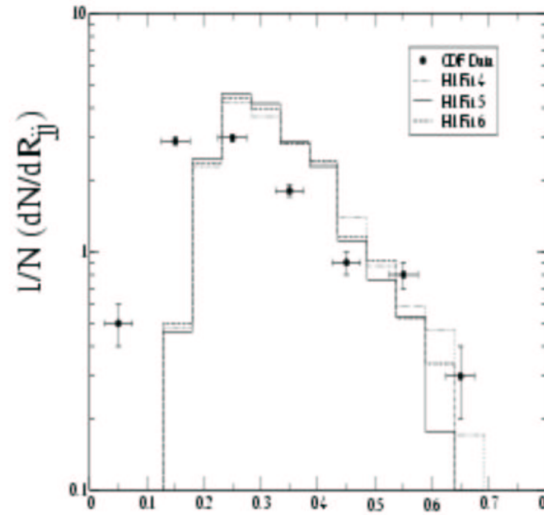
- Use to test calculations or to normalise calculations of diffractive Higgs:

## Exclusive Higgs Production

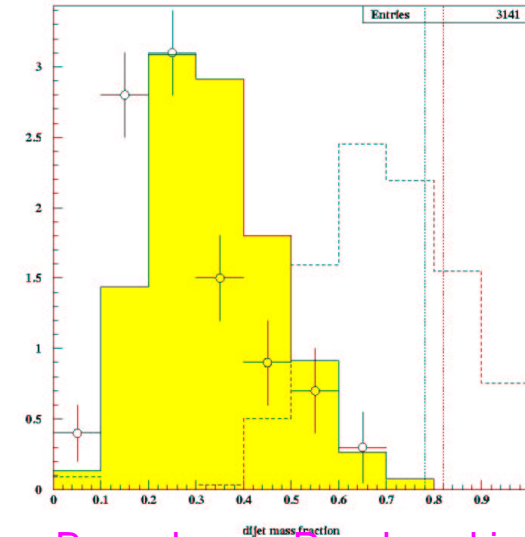


Khoze, Martin, Ryskin  
Eur. Phys J. C23, 211(2002)

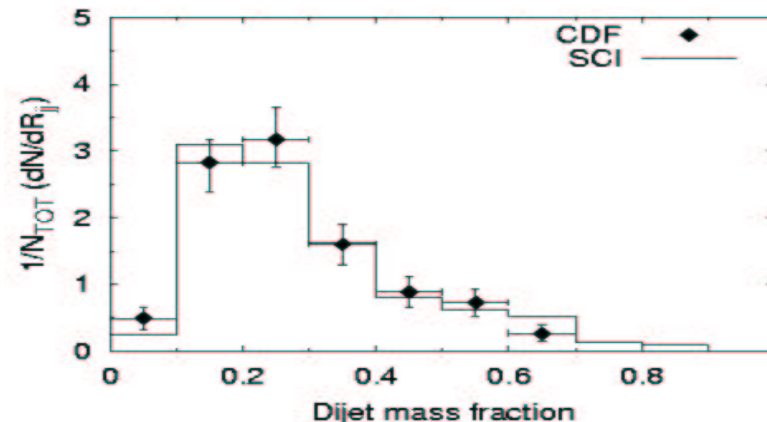
Exclusive dijets predict  
around **1nb** run I cuts  
60pb  $25 < E_{\text{+}} < 35 \text{ GeV}$ ,  $\Delta\eta < 1$ .



$R_{ij}$  Appleby, Forshaw  
Phy. Lett B541 (2002) 108



Boonekamp, Peschanski,  
Royon.  
Phys Lett 87 (201) 251806



Enberg, Ingelman and Timneanu  
Phys Rev Lett 89 (2002) 081801

# DPE Dijets: event selection

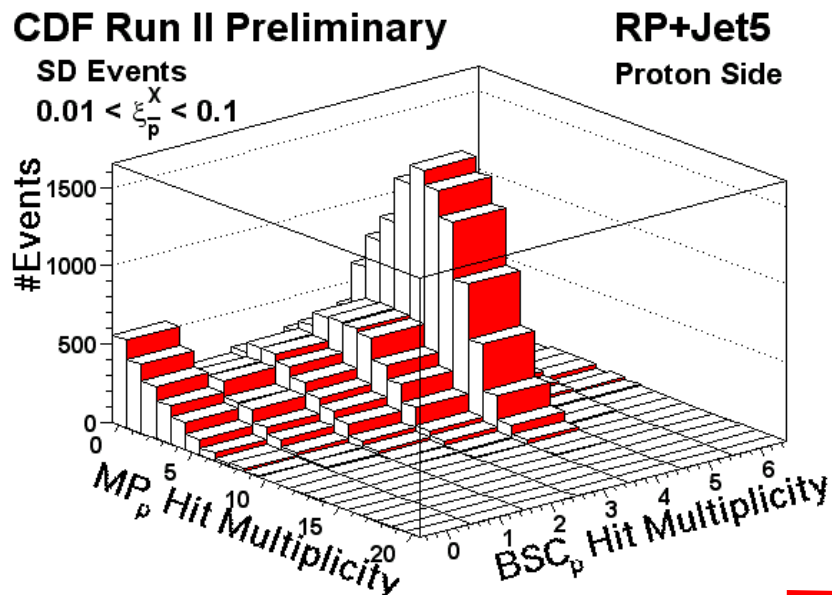
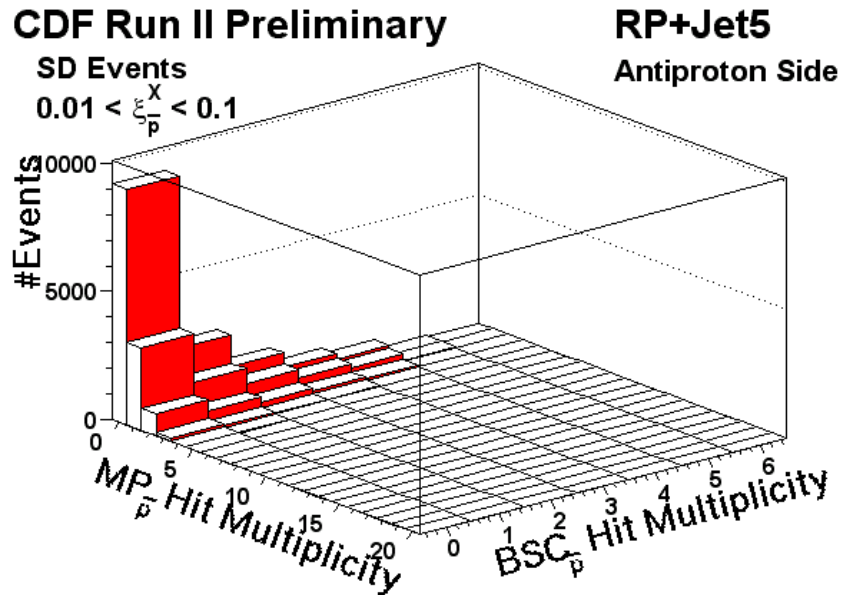
## Trigger Requirement

- Tag  $\bar{p}$  in roman pots
- Gap on  $p$ -side in BSC ( $5.5 < \eta < 7.5$ )
- Cal tower  $E_{\dagger} > 5$  GeV
- $26 \text{ pb}^{-1}$  prescaled x5

## Additional Event selection

- $0.03 < \xi_{\bar{p}} < 0.1$
- Gap in miniplug ( $3.6 < \eta < 5.1$ )
- $N(\text{good vertex}) \leq 1$
- No significant missing  $E_{\dagger}$
- 2+ jets (cone 0.7)  $E_{\dagger} > 10$  GeV  
(corrected  $E_{\dagger}$ ),  $|\eta_{1,2}| < 2.5$

→ x200 improvement in stats on run I

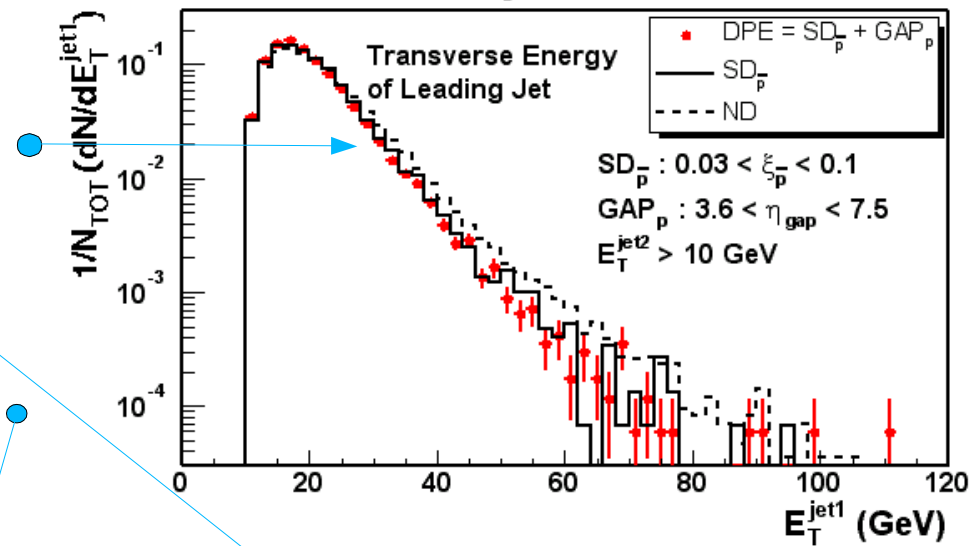


# DPE Dijets: kinematic properties

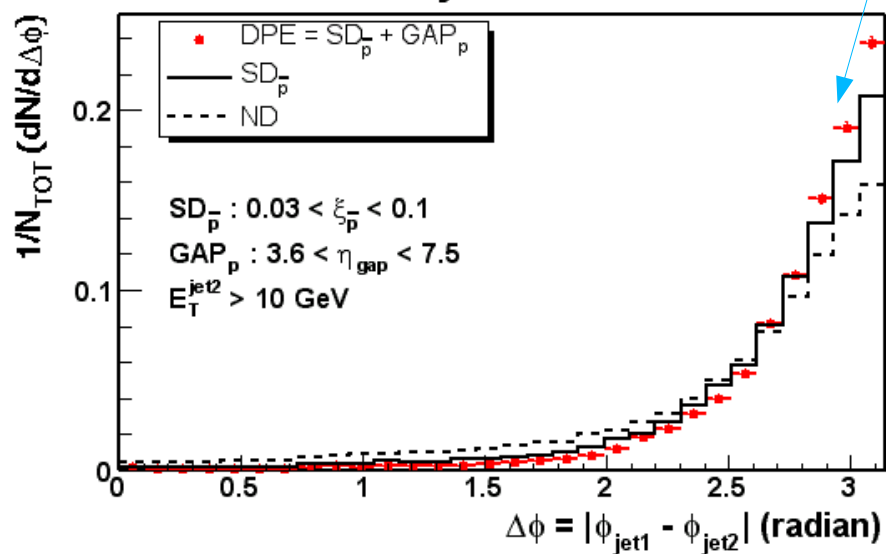
Jets in **DPE** compared to **SD**:

- Fairly **similar**  $E_T$  distribution
- Jets now almost **central** again ( $\xi_{\bar{p}} \sim \xi_p$ )
- Even more **back to back** in  $\phi$

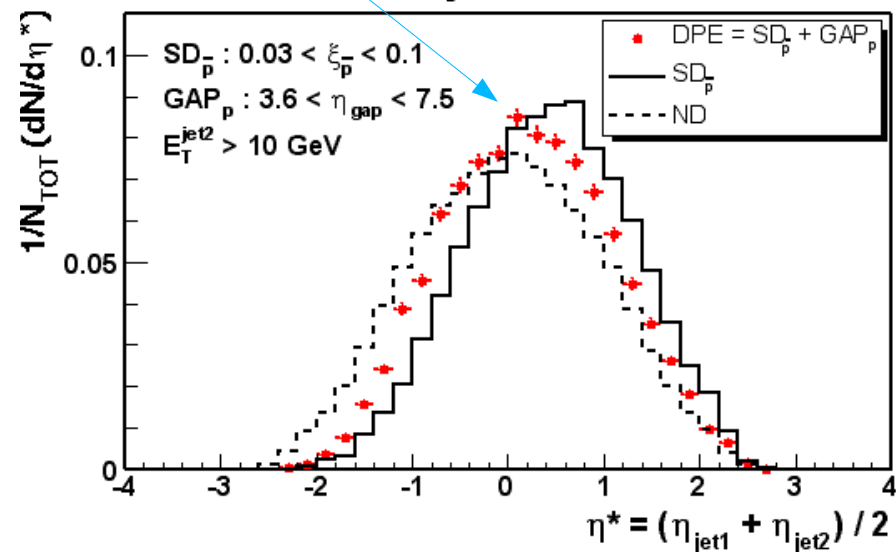
CDF Run II Preliminary



CDF Run II Preliminary



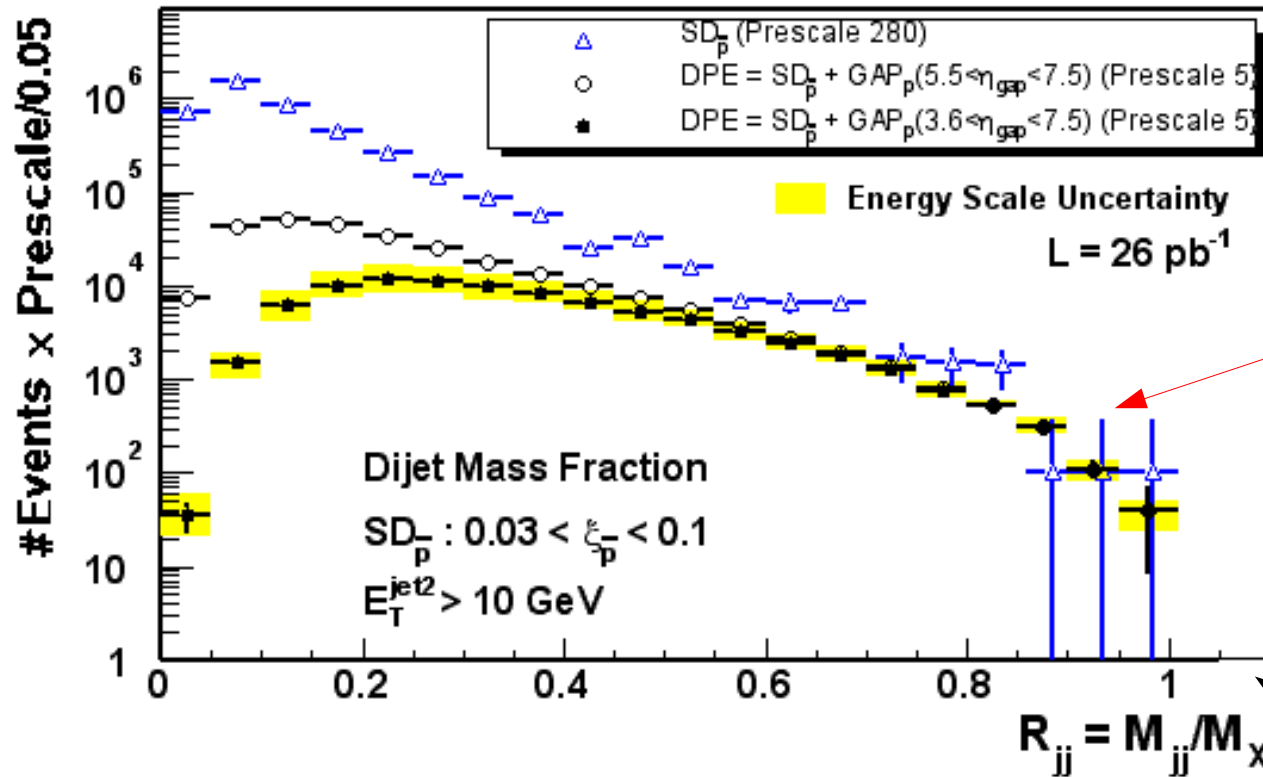
CDF Run II Preliminary





# DPE Dijets: Mass Fraction

CDF Run II Preliminary



$$R_{jj} = \frac{\text{Dijet Mass}}{\text{Diffractive Mass}}$$

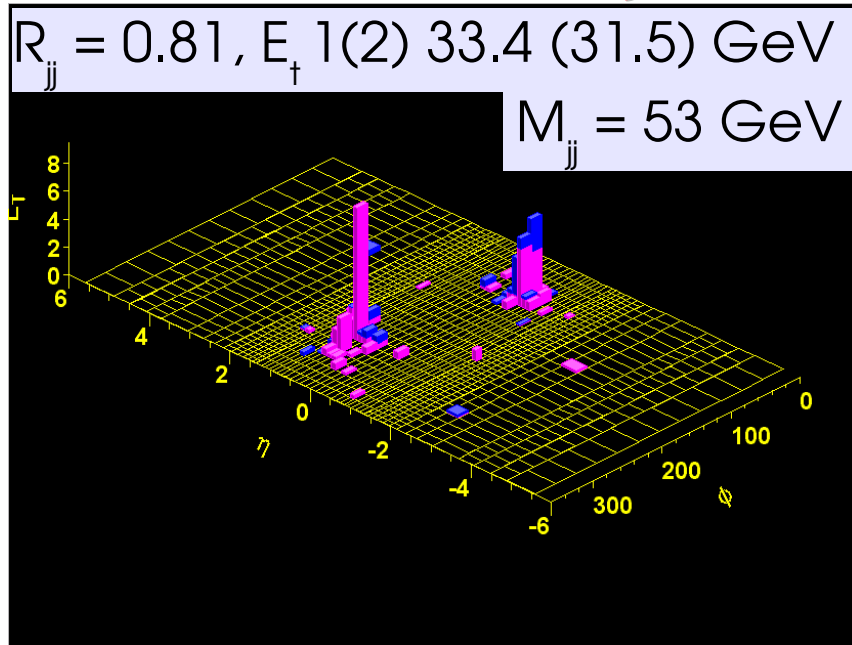
•  $R_{jj}$  will be large for exclusive events (but  $< 1$  due to out of cone energy)  
Smooth distribution

Note: •

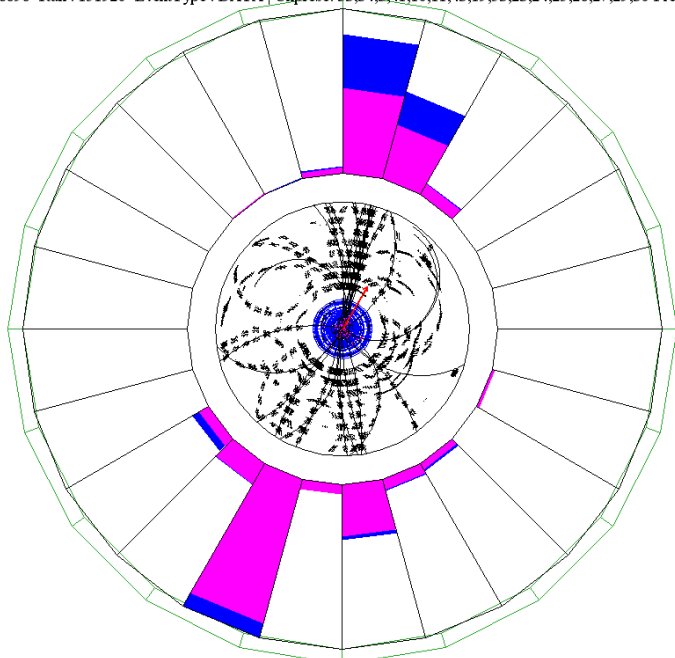
Here corrections for underlying event or to get the parton energy are not applied in the calculation of  $M_{jj}$

Min $E_t(\text{jet1})$	Cross Section ( $R_{jj} > 0.8$ )
10 GeV	$970 \pm 65 \text{ (stat)} \pm 272 \text{ (syst) pb}$
25 GeV	$34 \pm 5 \text{ (stat)} \pm 10 \text{ (syst) pb}$

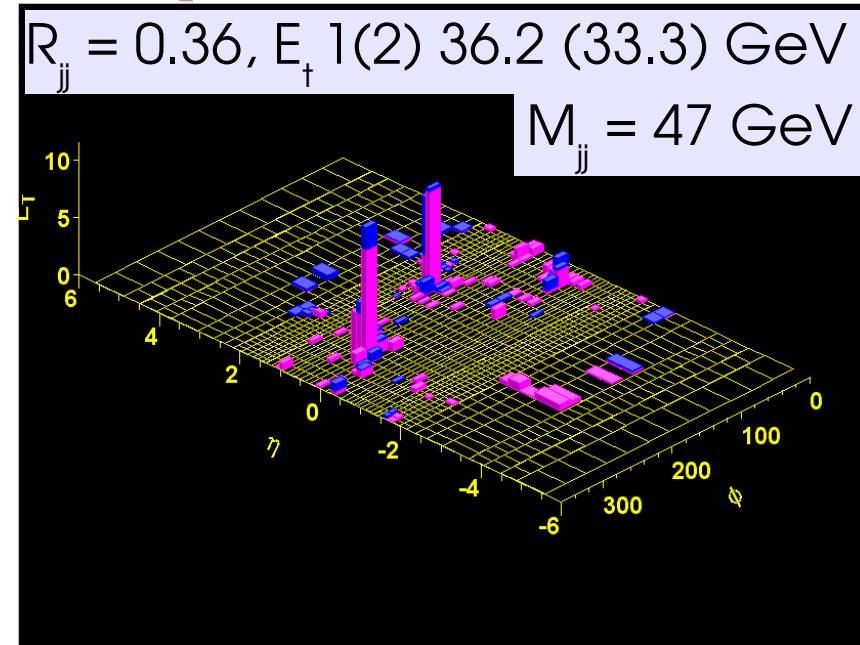
# DPE Dijets: event pictures



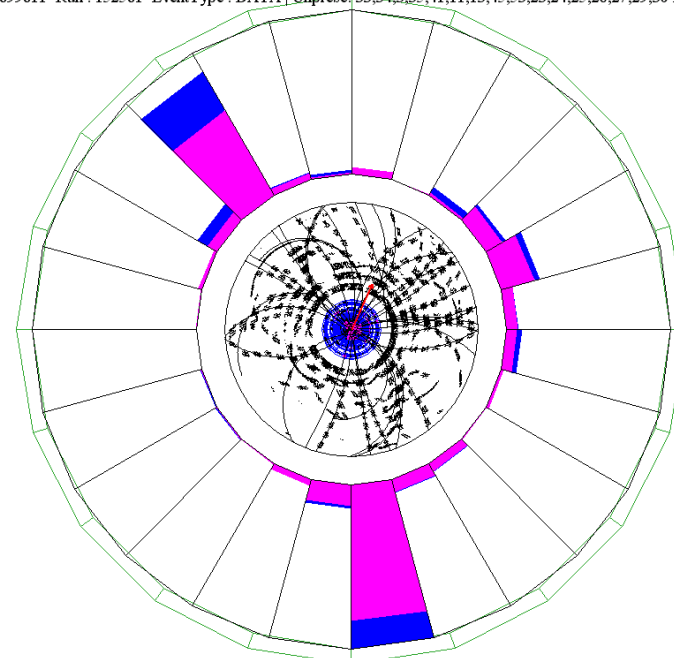
Event : 78696 Run : 151920 EventType : DATA | Unpresc: 33,34,3,41,10,11,43,19,53,23,24,25,26,27,29,30 Presc: 33,34,10,2



$E_{\text{t}} = 42.75 \text{ GeV}$



Event : 899811 Run : 152581 EventType : DATA | Unpresc: 33,34,3,35,41,11,13,45,53,23,24,25,26,27,29,30 Presc: 34,35,24,



$E_{\text{t}} = 31.25 \text{ GeV}$

# Outlook for CDF Diffraction

- **Diffraction Structure Functions:**
  - obtain  $\xi$  and  $Q^2$  dependence
  - measure for proton side of DPE events (factorisation test)
- **Double Pomeron Exchange:**
  - $J/\psi$  production
  - $b\bar{b}$  jets
  - exclusive low mass production
- **Gaps between jets**
  - miniplug gives jet separation of 9 units in rapidity
- **Multigap hard production**

# Exclusive Diffraction

$$p \bar{p} \rightarrow p + X + \bar{p}$$

- So far searches for:  
 $X = \text{jet-jet}$

- Currently trigger on:  
 $X = \chi_c$  (J/ψ trigger)  
 $X = \gamma\gamma$

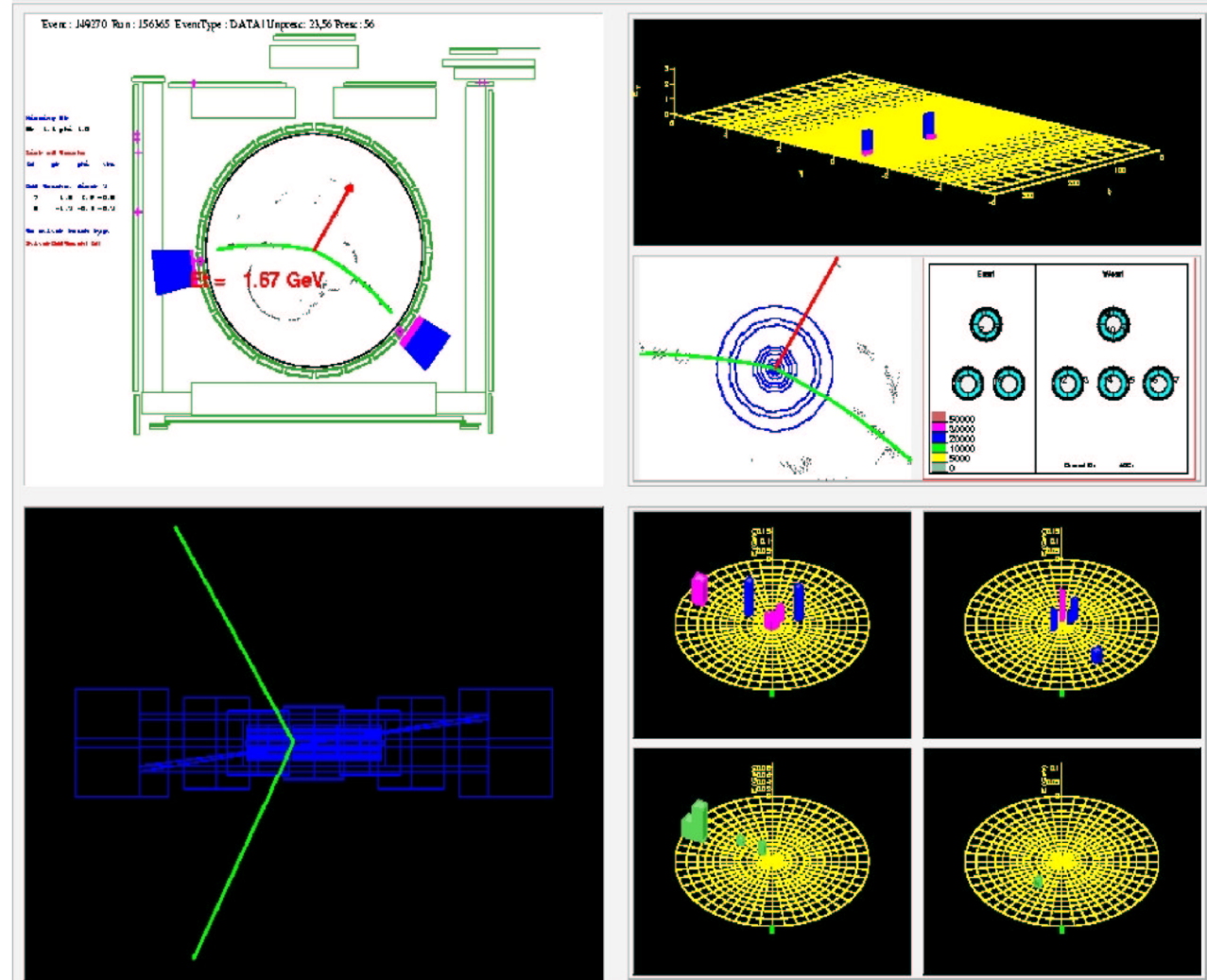
much lower cross section but **cleaner**

- Developing trigger for other **low-mass states**

Possible candidate (???) for

$$p \bar{p} \rightarrow p + \chi_c + \bar{p} \rightarrow p + J/\psi + \bar{p} \rightarrow p + \mu\mu\gamma + \bar{p}$$

- exclusive event with J/ψ and a conversion



# Summary

- CDF detector working beautifully.  
New BSC, mini-plug fully working, calibrated.
- Run II diffractive measurements consistent with Run I
- **New Results:**
  - Ratio of SD to ND rates shows no significant  $Q^2$  dependence
  - Huge increase (x200) in double pomeron exchange dijets sample
  - Dijets seen in exclusive region, but smooth distribution.
- Prospects look great for many new/improved measurements.